Appendix D: Airport Capacity Impacts of Airport and CNS/ATM Improvements[1]

This report describes how airport capacities were estimated for the study "The Impact of CNS/ATM Enhancements on Emissions" performed by and for ASD-430 in February through April 1998. The National Airspace System Performance Analysis Capability (NASPAC) Simulation Modeling System (SMS) was used to model two cases using these capacities: a baseline case and a case that included the effects of future communications, navigation, and surveillance (CNS) and Air-Traffic Management (ATM) improvements. The following scenarios were modeled:

Year Modeled	Cases Modeled	
1996	Baseline Case	-
2005	Baseline Case	CNS/ATM Improvement Case
2010	Baseline Case	CNS/ATM Improvement Case
2015	-	CNS/ATM Improvement Case

I. BASELINE-CASE AIRPORT CAPACITIES

The effects of physical airport improvements and new ATC procedures that do not require CNS/ATM improvements are reflected in the baseline capacities. Because no baseline case was analyzed for 2015, these baseline improvements were projected only to the year 2010.

A. Physical Airport Improvements

Physical changes to an airport can have a substantial impact on airport capacity. The effect can range from opening a new airport to adding new taxiways that streamline air-traffic operations. Runways can be extended to air-carrier length, allowing the airport to accommodate larger aircraft. Airport capacity can sometimes be increased by adding to the number of gates or adding room for aircraft to maneuver in the ramp area. However, the change that generally has the greatest impact on capacity is adding a new runway.

New runways are commonly built parallel to one or more existing runways so that parallel streams of traffic can be flown into and off of each runway. Separation between runways is critical; if two runways are built too close together, their operation under Instrument Flight Rules (IFR) may effectively be equivalent to a single runway. As a result, most new runways are built at least a half-mile apart (as measured from centerline to centerline). In IFR, dependent, staggered parallel approaches can be flown to parallel runways that are at least 2,500 feet apart, generating a 40-to-45 percent increase in arrival capacity over the capacity of a single runway. If parallel runways are at least 3,400 feet apart (3,000 feet apart for angled approaches) and a Precision Runway Monitor (PRM) is in use, independent parallel approaches can be flown in IFR, doubling the capacity of a single runway. (If no PRM is in use, 4,300 feet are required between runways to operate independent parallel approaches in IFR.)

[1] This appendix was developed by Dan Citrenbaum (FAA/ASD-400) and Willie Weiss (CSSI, Inc.).

There are other options that will increase airport capacity if there is insufficient space for an air-carrier length runway to be built at a separation that would allow independent parallel operations in IFR. In some cases, a shorter runway, designed for commuter and general-aviation aircraft, might be built at a separation that would allow independent operations in IFR, or an air-carrier-length runway might be built considerably closer to another runway. This runway would allow an independent stream of arrivals only under Visual Flight Rules (VFR) and is a viable alternative at generally fair-weather airports.

Table 1 shows the physical improvements that are expected to increase airport capacity during the 1996-2015 time frame among the 80 airports modeled in detail in NASPAC. Because arrival capacity is generally more restrictive than departure capacity, the increase in maximum arrival capacity is cited as a measure of the capacity increase. (Another reason for citing maximum arrival capacity is that many airports generally operate at or near maximum arrival capacity, again, because it is tends to be lower than maximum departure capacity.) Maximum arrival capacity will increase at 16 of these 80 airports during the 1996-to-2005 time frame. Capacity will increase at 7 additional airports by 2010. For the 1996-to-2005 time frame, the size of the increase is related to the number of runways in use in 1996 and is relative to the airport capacity in 1996, as well as to local ATC practices. (For the 2006-to-2010 time frame, the size of the increase relative to the airport capacity in 2005.) Also, note that the increase in capacity listed is for the effect of the new runway only; any further capacity increase due to CNS/ATM improvements or procedures that depend on CNS/ATM improvements is not included in this table. (The effects of those improvements are described later in this report.)

Table 1. Physical Airport Improvements Projected for 1996 - 2015

			Increase in Hourly Maximum Arrival Capacity		**%Weather***
Airport	**LocID**	**Improvement**	**VMC %** ***Add'l Ops***	**IMC %** ***Add'l Ops***	**< Viz Mins** ***< 1000/3***
1996 to 2005					
Atlanta Hartsfield	ATL	Commuter runway without PRM	50% *45*	15% *13*	30.6% *12.5%*
Austin	AUS	New airport (Bergstrom AFB conversion)	0% *0*	100% *23*	28.9% *12.2%*
*The percentage of the airport's weather below visual minimums and below a 1,000-foot ceiling or 3-miles visibility (in italics) were derived from the airport's visual approach minimums and the National Climatic Data Center's International Station Meteorological Climate Summary data set. Each value in the data set are based on the average of many years of observations; values for the top 10 airports, for example, are based on an average of 40 years of observations. In the analysis, IMC operations were assumed to be flown below visual minimums. Because visual minimums vary by airport, the percent weather below 1,000/3 is included as a consistent basis of comparison of IMC weather between airports.					
Charlotte Douglas	CLT	Parallel runway (dependent in IMC)	45% *35*	21% *14*	24.2% *12.0%*
Cincinnati	CVG	New parallel	50%	50%	17.4%

			Increase in Hourly Maximum Arrival Capacity		**%Weather***
Airport	**LocID**	**Improvement**	**VMC %** ***Add'l Ops***	**IMC %** ***Add'l Ops***	**< Viz Mins** ***< 1000/3***
		(independent triple IMC approaches)	*33*	*30*	*11.9%*
Cleveland Hopkins	CLE	Close parallel runway	60% *24*	0% *0*	23.7% *11.5%*
Dallas-Fort Worth	DFW	New parallel runway will enable quadruple IMC apps.	25% *35*	33% *35*	18.1% *6.0%*
Detroit Metropolitan	DTW	New parallel runway will enable triple IMC apps.	39% *35*	33% *22*	39.6% *12.2%*
Louisville	SDF	New parallel (independent parallel approaches)	100% *35*	100% *32*	22.3% *7.6%*
Miami	MIA	Close parallel (increased VFR departure capacity)	0% *0*	0% *0*	5.2% *1.7%*
Minneapolis	MSP	New runway	15% *10*	21% *10*	27.6% *8.4%*
New Orleans	MSY	New parallel (independent approaches)	10% *6*	100% *33*	22.6% *8.7%*
Orlando	MCO	New parallel (independent triple approaches)	47% *35*	50% *29*	24.6% *5.8%*
Philadelphia	PHL	New staggered parallel (dependent approaches without PRM)	66% *37*	44% *14*	18.3% *13.0%*
Phoenix	PHX	New parallel (independent parallel approaches)	0% *0*	100% *32*	2.8% *0.3%*
Seattle	SEA	New parallel (dependent parallel approaches)	0% *0*	46% *12*	30.5% *10.5%*
St. Louis	STL	New offset parallel without PRM (dependent parallel approaches)	12% *9*	2% *1*	35.6% *9.8%*

			Increase in Hourly Maximum Arrival Capacity		**%Weather***
Airport	**LocID**	**Improvement**	**VMC %** ***Add'l Ops***	**IMC %** ***Add'l Ops***	**< Viz Mins** ***< 1000/3***
*The percentage of the airport's weather below visual minimums and below a 1,000-foot ceiling or 3-miles visibility (in italics) were derived from the airport's visual approach minimums and the National Climatic Data Center's International Station Meteorological Climate Summary data set. Each value in the data set are based on the average of many years of observations; values for the top 10 airports, for example, are based on an average of 40 years of observations. In the analysis, IMC operations were assumed to be flown below visual minimums. Because visual minimums vary by airport, the percent weather below 1,000/3 is included as a consistent basis of comparison of IMC weather between airports.					
2006 Through 2010					
Baltimore-Washington	BWI	New parallel runway	33% *17*	71% *20*	14.0% *9.0%*
Denver	DEN	New parallel runway (6th runway)	29% *35*	14% *15*	8.3% *5.3%*
Jacksonville	JAX	New parallel (independent IMC approaches)	33% *16*	100% *28*	32.3% *9.4%*
Los Angeles International	LAX	New, close parallel runway	42% *35*	0% *0*	31.1% *15.8%*
Pittsburgh	PIT	New parallel runway (triple independent IMC apps.)	40% *34*	50% *32*	25.6% *13.6%*
Tampa	TPA	New, close parallel runway	0% *0*	6% *4*	8.3% *5.4%*
Washington Dulles	IAD	New parallel runway	14% *13*	0% *0*	27.6% *11.3%*

*The percentage of the airport's weather below visual minimums and below a 1,000-foot ceiling or 3-miles visibility (in italics) were derived from the airport's visual approach minimums and the National Climatic Data Center's International Station Meteorological Climate Summary data set. Each value in the data set are based on the average of many years of observations; values for the top 10 airports, for example, are based on an average of 40 years of observations. In the analysis, IMC operations were assumed to be flown below visual minimums. Because visual minimums vary by airport, the percent weather below 1,000/3 is included as a consistent basis of comparison of IMC weather between airports.

Table 1 shows a smaller-than-expected increase in IFR capacity due to the new runways at ATL, PHL, and STL. This is because the new runways were built at a separation designed to take advantage of the Precision Runway Monitor (PRM). This is an example of the interaction between CNS/ATM improvements and physical improvements (included in the CNS/ATM Improvements cases but excluded from the baseline-case improvements described above).

B. ATC Procedural Improvements

Changes in ATC procedures can also have a significant effect on airport capacity. New procedures can increase the utilization of existing runways, or they can work in concert with new runways and with CNS/ATM improvements.

In the future, it is expected that converging IFR approaches will be added to independent parallel IFR approaches. This procedure will greatly increase capacity at airports with the appropriate configurations, such as Chicago O'Hare or Washington Dulles.

Independent converging IFR approaches can be flown to converging runways that have sufficient separation between runway thresholds, or to airports without sufficient separation, but at higher approach minimums. This procedure substantially increases IFR capacity at airports without parallel runways.

Dependent Converging Instrument Approaches (DCIA) allow controllers to direct two dependent streams of arriving aircraft to converging and even intersecting runways. Consecutive arrivals in each stream are staggered to separate the aircraft. An ARTS modification, called the Converging Runway Display Aid, enables controllers to maintain the correct separations.

In some cases, the addition of a navaid can increase airport capacity by allowing a new procedure. At Portland, a recently added Instrument Landing System (ILS) allows controllers to use dependent (staggered) parallel approaches.

Table 2 shows the procedural improvements predicted for airports modeled in detail in NASPAC for the 1996 - 2010 time period.

There were no known, new procedures beyond the 2010 time frame that could be included in this analysis.

Table 2. Procedural Airport Improvements Projected for 1996 - 2010

Airport	**LocID**	**Improvement**	**Increase in Hourly Max. IMC Arrival Capacity in % and *Add'l Ops***	**%Weather* < Viz Mins *< 1000/3***
Baltimore-Washington	BWI	DCIA	71% *20*	14.0% *9.0%*
Chicago O'Hare	ORD	Parallel plus converging IFR approaches	44% *30*	39.8% *10.9%*
Las Vegas	LAS	Independent converging IFR approaches	44% *16*	1.2% *0.3%*
Newark	EWR	DCIA	25% *9*	17.7% *11.8%*
Portland	PDX	Dependent parallel approaches	45% *14*	33.0% *6.7%*
San Francisco	SFO	DCIA	14% *5*	25.9% *8.7%*
Tampa	TPA	Parallel plus converging IFR approaches	38% *18*	8.3% *5.4%*
Washington Dulles	IAD	Parallel plus converging IFR approaches	43% *25*	27.6% *11.3%*

*The percentage of the airport's weather below visual minimums and below a 1,000-foot ceiling or 3-miles visibility (in italics) were derived from the airport's visual approach minimums and the National Climatic Data Center's International Station Meteorological Climate Summary data set.

II. CNS/ATM-IMPROVEMENTS CASE AIRPORT CAPACITIES

CNS/ATM improvements tend to increase capacity incrementally at the airports they affect. They may also work in concert with new runways. For example, an airport expecting a PRM can build a parallel runway at a separation of as little as 3,400 feet, rather than the standard 4,300-foot separation. This saves the airport operator land-acquisition costs and minimizes the environmental and noise impacts of the new runway.

A. Precision Runway Monitor

The PRM includes a high-update-rate, high-resolution radar and high-resolution, color display. FAA procedures allow straight-in, simultaneous Instrument Flight Rules (IFR) approaches to parallel runways with centerlines separated by as little as 3,400 feet if a PRM is in use. (The minimum distance between runway centerlines required for simultaneous IFR approaches is 4,300 feet if a PRM is *not* in use.) Simultaneous approaches to runways with centerlines separated by as little as 3,000 feet may be conducted using a PRM if 2.5-degree angled approaches are flown to one of the runways.

PRMs increase airport capacity because they enable simultaneous approaches to parallel runways where those approaches would otherwise not be possible. PRMs are being installed at five airports (Table 3) and will increase capacity over and above the capacity increase due to a new runway, where one is being built. (The capacity increases due to PRM shown in Table 3 vary because they are relative to the capacity of the best existing configuration. That is, if the best existing configuration has a high capacity, the relative increase due to the PRM will not be as large as it would be compared to a low-capacity configuration. However, even at airports that already have a high-capacity IMC configuration, a PRM may greatly increase overall airport capacity by supplying another high-capacity IMC configuration.)

New runways are being built at ATL, PHL, and STL to take advantage of the PRM. Existing runways will be used with PRMs at JFK and MSP. (Note that the capacity increases shown in Table 3 for ATL, PHL and STL do *not* include the increase due to the new runway; that increase is shown in Table 1.)

A PRM installation also implies a new procedure, in that PRM use allows an airport to operate independent, instead of dependent, parallel IFR approaches.

Table 3. Estimated Capacity Improvement Due Solely to PRM

Airport	LocID	Increase in Hourly Max. IMC Arrival Capacity in % and *Add'l Ops*	Expected Operational Date	%Weather* < Viz Mins *< 1000/3*
Atlanta Hartsfield	ATL	18% *18*	2002	30.6% *12.5%*
Minneapolis	MSP	35% *17*	September 1998	27.6% *8.4%*
New York JFK	JFK	20% *10*	August 1999	18.4% *12.1%*
Philadelphia	PHL	39% *18*	2000	18.3% *13.0%*
St. Louis	STL	40% *19*	2003	35.6% *9.8%*

B. Center-TRACON Automation System (CTAS)

CTAS is a decision-support system designed to help air traffic controllers and managers accurately predict aircraft arrival trajectories in the terminal area. CTAS also enables controllers to more accurately deliver aircraft over the runway threshold, reducing excess spacing buffers between flights and thus increasing airport capacity.

The CTAS benefits applied to those airports slated for CTAS were estimated from studies of two CTAS elements: the Passive Final Approach Spacing Tool (Passive FAST) and the Traffic Management Advisor (TMA).

In demonstrations at the terminal area surrounding Dallas-Fort Worth International Airport (DFW), Passive FAST decreased the mean separation between arriving aircraft through improved runway load balancing, more accurate aircraft sequencing, and reduced variability in longitudinal separation between aircraft. Controllers aided by Passive FAST were better able to anticipate the characteristics of the upcoming arrival stream and to direct aircraft to the best runway. This reduced delays to upstream aircraft and eliminated the need to redirect other upstream aircraft. In a comparison of 20 Passive FAST and 26 baseline-case events, the mean peak-period spacing between aircraft was 87.8 seconds for Passive FAST operations and 91.9 seconds for baseline operations, a spacing reduction of 4.1 seconds. Additionally, Passive FAST was found to decrease interarrival separation over the entire demand profile, from low demand to arrival rushes. (These results are documented in "Center/TRACON Automation System Passive Final Approach Spacing Tool (FAST) Assessment–Final Report," 5 December 1996, Crown Communications report number CTASDS-BAPRPT-002.)

TMA Time-Based Metering was also demonstrated at DFW. TMA improved metering fix accuracy and decreased threshold arrival stream gaps, thus reducing threshold separations. TMA was shown to reduce the mean interarrival threshold spacing buffer by 2.75 seconds over the baseline case. (This is documented in the briefing "CTAS Benefits Extrapolation First-Cut Analysis, given to FAA staff by Tara Weidner, George Couluris, and George Hunter of Seagull Technology, Inc. on August 20, 1997. A report is not yet available.)

Experts with the CTAS program were consulted; they determined that these spacing reductions (of 4.1 and 2.75 seconds) were both conservative and additive and applied to both Visual and Instrument Flight Rules operations. However, they also determined that the 4.1-second reduction due to Passive FAST could only be obtained at airports running 3 or more streams of arrivals. It was estimated that only 0.25 of that reduction could be obtained at airports with less than 3 arrival streams, and thus that value was added to the 2.75 seconds due to TMA at the appropriate airports.

The CTAS program reported that these benefits will be available by the year 2005, and thus the impacts they will have on airport capacity were included for the years 2005 and 2010. It is important to note that these benefits decrease interarrival separations, leaving less time to release departures. Thus, in the inputs to the NASPAC Simulation Modeling System, maximum arrival capacity was increased, but minimum departure capacity was reduced. This had a significant positive impact on airport delays despite the fact that the capacities satisfying 50/50 arrival/departure demand were generally unchanged.

To illustrate the relative improvement due to CTAS, Table 4 shows the estimated maximum IMC arrival capacity improvement due to CTAS. (Capacity also increased in VMC; however, these increases are similar to those shown in Table 4 and thus are not shown.)

Table 4. Estimated Capacity Improvement Due to CTAS

			Increase in Hourly Maximum IMC Arrival Capacity	
Airport	**LocID**	**No. of Arrival Streams**	**Percent**	**Number of Additional Ops.**
Atlanta	ATL	3	7.7%	9
Boston	BOS	2	1.9%	1

			Increase in Hourly Maximum IMC Arrival Capacity	
Airport	**LocID**	**No. of Arrival Streams**	**Percent**	**Number of Additional Ops.**
Burbank	BUR	1	2.9%	1
Charlotte	CLT	2	8.8%	7
Chicago Midway	MDW	1	3.2%	1
Chicago O'Hare	ORD	2	5.1%	5
Cincinnati	CVG	2	4.4%	4
Cleveland	CLE	2	2.0%	1
Dallas Love	DAL	2	2.2%	1
Dallas-Ft. Worth	DFW	4	7.1%	10
Denver	DEN	3	7.4%	8
Detroit	DTW	3	5.7%	5
Houston Hobby	HOU	1	3.2%	1
Houston Intercontinental	IAH	3	4.2%	3
John Wayne/ Orange Cnty.	SNA	1	3.0%	1
Las Vegas	LAS	2	1.9%	1
Long Beach	LGB	1	3.3%	1
Los Angeles	LAX	3	4.4%	3
Louisville	SDF	2	3.1%	2
Memphis	MEM	2	4.0%	3
Miami	MIA	2	3.0%	2
Minneapolis	MSP	2	3.1%	2
Nashville	BNA	2	3.6%	2
New York La Guardia	LGA	1	2.9%	1
New York JFK	JFK	2	3.3%	2
Newark	EWR	2	3.7%	2
Oakland	OAK	2	3.3%	2
Ontario	ONT	1	3.6%	1
Orlando	MCO	3	5.7%	5
Philadelphia	PHL	2	3.1%	2
Phoenix	PHX	2	3.1%	2
Pittsburgh	PIT	3	4.7%	3
Portland	PDX	2	2.2%	1
Salt Lake City	SLC	2	3.2%	2
San Diego	SAN	1	3.1%	1
San Francisco	SFO	2	2.5%	1

			Increase in Hourly Maximum IMC Arrival Capacity	
Airport	**LocID**	**No. of Arrival Streams**	**Percent**	**Number of Additional Ops.**
Seattle	SEA	2	2.6%	1
St. Louis	STL	2	3.0%	2
Washington Dulles	IAD	3	6.0%	5
Washington National	DCA	1	2.9%	1
White Plains, NY	HPN	1	3.3%	1

C. Integrated Terminal Weather System (ITWS) Terminal Winds Product

In prototype testing, controllers at Dallas-Fort Worth (DFW) used more accurate wind predictions from the Terminal Winds Product (TWP) to merge and sequence traffic more precisely. They used the improved wind projections to pass requests for wind-specific separations to upstream controllers, thus coordinating the longitudinal separations between aircraft throughout the terminal area.

One example of the benefits of the TWP is when a strong northwest wind is blowing at altitude at the northwest arrival gate ("Terminal Winds Operational Benefits for Dallas/Ft. Worth," 8 March 1996, MIT Lincoln Labs Memorandum No. 43PM-Wx-0039). Controllers are required to merge arrivals through that gate with arrivals through the southwest gate, where a crosswind exists in these conditions. The aircraft must be merged at the base leg of the final approach to runway 36L, and the large speed difference between aircraft approaching quickly through the northwest gate and aircraft flying at nominal speed through the southwest gate makes it very difficult for controllers to space and merge these aircraft in a way that produces optimal separations on final approach. Using TWP, controllers can adjust the speeds and spacing of aircraft approaching from the northwest gate, optimizing the separations on final approach for 36L and thus increasing airport capacity.

The result of these more-precise separations on final approach was an increase in airport capacity estimated by DFW controllers at 2.5 additional arrivals per runway per hour in low-ceiling and low-visibility conditions ("Integrated Terminal Weather System (ITWS) Terminal Winds Operational Benefits for New York City Airports," 24 February 1997, MIT Lincoln Labs Memorandum No. 43PM-Wx-0048). This estimate was then extrapolated to those airports slated for ITWS installations by increasing their maximum arrival capacity per arrival runway by that amount. Table 5 shows the estimated increase in hourly maximum arrival capacity due to the ITWS TWP.

Table 5. Estimated Capacity Improvement Due to ITWS

Airport	LocID	No. of Arrival Streams	Increase in Hourly Maximum IMC Arrival Capacity: Percent	Increase in Hourly Maximum IMC Arrival Capacity: No. of Add'l Ops.
Atlanta	ATL	3	5.6%	7
Baltimore	BWI	2	17.9%	5
Boston	BOS	2	9.4%	5
Charlotte	CLT	2	5.7%	5
Chicago Midway	MDW	1	6.3%	2
Chicago O'Hare	ORD	2	4.9%	5
Cincinnati	CVG	2	5.3%	5
Cleveland	CLE	2	9.8%	5
Columbus, OH	CMH	2	11.6%	5
Dallas Love	DAL	2	10.6%	5
Dallas-Ft. Worth	DFW	4	6.7%	10
Dayton	DAY	2	8.3%	5
Denver	DEN	3	6.0%	7
Detroit	DTW	3	7.5%	7
Ft. Lauderdale	FLL	2	8.6%	5
Houston George Bush	IAH	3	9.3%	7
Houston Hobby	HOU	1	6.3%	2
Indianapolis	IND	2	7.8%	5
Kansas City	MCI	2	7.4%	5
Louisville	SDF	2	7.6%	5
Memphis	MEM	2	6.4%	5
Miami	MIA	2	7.4%	5
Milwaukee	MKE	1	6.3%	2
Minneapolis	MSP	2	7.5%	5
Nashville	BNA	2	8.8%	5
New Orleans	MSY	2	8.1%	5
New York La Guardia	LGA	1	5.7%	2
New York JFK	JFK	2	9.7%	6
Newark	EWR	2	10.7%	6
Oklahoma City	OKC	2	8.3%	5
Orlando	MCO	3	7.6%	7
Palm Beach	PBI	1	5.4%	2
Philadelphia	PHL	2	7.6%	5
Phoenix	PHX	2	7.6%	5
Pittsburgh	PIT	3	10.4%	7
Raleigh-Durham	RDU	2	10.6%	5
Salt Lake City	SLC	2	7.8%	5

			Increase in Hourly Maximum IMC Arrival Capacity	
Airport	LocID	No. of Arrival Streams	Percent	No. of Add'l Ops.
St. Louis	STL	2	7.4%	5
Tampa	TPA	2	7.7%	5
Tulsa	TUL	2	8.3%	5
Washington Dulles	IAD	3	8.0%	7
Washington National	DCA	1	5.7%	2
Wichita	ICT	2	8.6%	5

D. Weather Systems Processor

The Airport Surveillance Radar-Weather Systems Processor (WSP) is a lower-cost system similar to ITWS that will supply some ITWS products to medium and smaller air-traffic-density airports. Of all the NASPAC airports at which it may be installed, its effects on capacity were only significant at LAX, where WSP is predicted to increase maximum arrival capacity by 7.0%.

E. Automatic Dependent Surveillance-Broadcast/Cockpit Display of Traffic Information (ADS-B/CDTI)

The combination of GPS, ADS-B, and CDTI has the potential to enhance visual approaches and thus increase airport capacity. ADS-B/CDTI may help pilots in several ways:

- Help them visually acquire traffic more quickly
- Help them positively identify traffic
- Provide a means of highlighting particular aircraft
- Provide ground speed, closure rate, and/or ground-track information

All of these elements are likely to enhance the safety of visual approaches. And, if the traffic display is reliable enough, pilots could use it to keep traffic electronically "in view" during poor-visibility conditions. All of these elements may allow a reduction in the ceiling and visibility requirements for visual approaches.

In the paper entitled "Potential ADS-B/CDTI Capabilities for Near-Term Deployment" (Mundra, et al, June 16, 1997, The MITRE Corporation, for the FAA/EUROCONTROL ATM R&D Conference), the authors discuss the potential reduction in the minimum ceiling and visibility required for visual approaches into several major airports. The ceiling and visibility reductions for those five airports (DFW, JFK, SEA, SFO, and STL) were used to modify the NASPAC scenario days for the CNS/ATM scenarios in this analysis. Because this enhancement is unlikely to be restricted to those five airports, the ceiling and visibility reductions were extrapolated to the 30 busiest airports, all of which are modeled in detail in NASPAC. The result of these modifications to the scenario days is an increase the time visual approaches can be flown into these airports.

To modify the scenario days, the average reduction in ceiling and visibility were computed for the five airports discussed in the paper described above. These average reductions (1,000 feet in ceiling and 1.5 miles in visibility) were then applied to the visual-approach ceiling and visibility minimums for the 30 busiest airports, with the exception of the five airports themselves. (The reductions listed in the paper were used for those five airports discussed in the paper.) Ceiling and visibility were *not* reduced to less than 1,000 feet and 3 miles.

To reflect the impacts in the NASPAC scenario days, the amount of time that an airport was in Visual Meteorological Conditions (VMC) was increased to reflect the lowering of the visual-approach minimums for flying. This was done by consulting a 30-to-45-year summary of airport weather conditions, called the International Station Meteorological Climate Summary, obtained from the National Climatic Data Center. The average percent of the time that the weather exceeded the current visual-approach minimums was extracted from that data set for each of the 30 busiest airports. Then, the average percent of the time that the weather exceeded the reduced visual-approach minimums was extracted from the data set and the difference in time was computed for each airport. That difference in time was used to increase the time that each airport ran visual approaches in the NASPAC simulation scenario days for the CNS/ATM case. The NASPAC SMS was then executed for the CNS/ATM case using the revised scenario days.

Table 6 shows the estimated increase in VMC due to the enabling of "electronic VFR" by ADS-B and CDTI. The effect of this increase in VMC in the NASPAC scenario days was to increase the amount of time that visual approaches were flown at airports, thus increasing airport capacity. Note that, because visual-approach minimums vary by airport, the percent increase in IMC due to ADS-B and CDTI also varies by airport.

Table 6. Estimated Increase in VMC Due to ADS-B/CDTI

LocID	Average Percent Increase in VMC	LocID	Average Percent Increase in VMC
ATL	3.4%	MCO	3.1%
BOS	11.2%	MEM	2.4%
CLT	3.9%	MIA	2.1%
CVG	3.7%	MSP	2.9%
DCA	3.6%	OAK	7.3%
DEN	1.9%	ORD	5.8%
DFW	3.9%	PDX	2.8%
DTW	8.9%	PHL	4.1%
EWR	3.5%	PHX	0.8%
IAD	13.2%	PIT	8.0%
IAH	3.5%	SEA	4.3%
JFK	2.6%	SFO	6.5%
LAS	0.8%	SLC	1.8%
LAX	2.4%	SNA	2.5%
LGA	4.2%	STL	2.7%

Because the increase in capacity due to ADS-B/CDTI manifests itself in an increase in the amount of time an airport can operate visual approaches, rather than a direct increase in airport capacity, it is impossible to cite the size of the capacity increase here. However, the impacts of that capacity increase on delays are reflected in the results of the NASPAC SMS runs. It is also important to note that the percent VMC reflects not only weather, but also the visual approach minimums for each airport. If an airport has high minimums, its percent VMC may be considerably lower than the percent VMC for another airport with lower minimums.

F. Using ADS-B/CDTI to Operate Simultaneous Parallel IFR Approaches

The combination of GPS (augmented using WAAS or LAAS), ADS-B, and CDTI may also be used in the future to provide guidance for simultaneous independent parallel IFR approaches. In effect, this combination of navaids may be used in the same way a PRM is used now for these approaches. For this effort, it was assumed that runway centerlines must be separated by 2,500 feet for straight-in parallel IFR approaches to be flown to ILS Category I minimums. (Closer separations may be possible using angled approaches, but these would most likely be to higher-than-CAT I minimums.)

Table 7 shows the airports that are likely candidates for this combination of navaids and approaches.

Table 7. Estimated Capacity Improvement Using ADS-B/CDTI for Independent Parallel Approaches

		Increase in Hourly Maximum IMC Arrival Capacity	
Airport	**LocID**	**Percent**	**No. of Add'l Ops.**
Charlotte	CLT	24%	22
Detroit	DTW	13%	13
Nashville	BNS	47%	29
Portland	PDX	35%	16
Seattle	SEA	44%	17

G. Using WAAS or LAAS for Offset Approaches

Localizer/Distance Measuring Equipment (LDA) approaches are flown to some airports today using an offset ILS localizer while aircraft fly a standard ILS approach to the parallel runway. In the offset approach, the aircraft fly an approach to a localizer offset from the runway centerline and then "sidestep" to the runway approximately 3 miles from the runway threshold. This type of approach allows aircraft on parallel approaches to maintain separation until they are only a short distance from the runway threshold. One example is the LDA approach to STL runway 12L.

Offset approaches could enable either dependent or independent IFR approaches to parallel runways. However, it should be noted that these approaches can generally *not* be flown to ILS CAT I minimums. This procedure could be duplicated by 2005, using WAAS or LAAS for guidance. Table 8 shows the estimated increase in maximum arrival capacity at airports that are candidates for this procedure.

Table 8. Estimated Capacity Improvement Using WAAS or LAAS for Independent Parallel Approaches

		Increase in Hourly Maximum IMC Arrival Capacity	
Airport	**LocID**	**Percent**	**No. of Add'l Ops.**
Boston	BOS	21%	9
Cleveland	CLE	19%	8
Colorado Springs	COS	100%	24
Newark	EWR	20%	9
Fort Lauderdale	FLL	100%	27

Note that the variability in the impact of these approaches is dependent on the existing airport configuration and its capacity. If an airport has only a single approach in IMC, then adding these approaches could double its capacity.

III. COMPARISON OF CAPACITY IMPROVEMENTS

The following two tables list the estimated increase in maximum IFR arrival capacity for each type of improvement. In Table 9, physical and procedural improvements are listed for the baseline case. The capacity increase associated with each improvement excludes any contribution by CNS/ATM systems.

Because some runways have been built with the PRM in mind, IFR capacity may increase only slightly due to those runways if the scheduled PRM is not installed (a very unlikely prospect). Also, close-parallel runways will not affect IFR capacity significantly. The effects of these two types of new runways are not included in this chart so that the results are not skewed.

Table 9. Baseline Case Physical and Procedural Improvements

Improvement	No. of Affected Airports	Average Estimated Increase in Max. Hourly IFR Arrival Cap.	
		Percent	No. of Add'l Ops.
Physical Improvements 1997-2005 (excluding close parallels and runways designed for use with PRM)	12	53%	22
Physical Improvements 2006-2010 (excluding close parallels at LAX and TPA)	6	40%	16
Procedural Improvements 1996-2010	8	41%	17

Table 10 lists the estimated increase in maximum IFR arrival capacity for CNS/ATM improvements. The PRM, ADS-B/CDTI parallel approaches, and WAAS/LAAS parallel approaches are all similar types of improvements, in that each is associated with a new procedure and a new type of surveillance. Each allows an airport to operate another independent stream of IFR arrivals. These improvements provide a significant increase in capacity. However, ITWS and CTAS, although applicable at many airports, provide only an incremental increase in capacity.

Table 10. CNS/ATM Case Improvements

CNS/ATM Improvements	No. of Affected Airports	Average Estimated Increase in Max. Hourly IFR Arrival Cap.	
		Percent	No. of Add'l Ops.
PRM	5	30%	16
CTAS	41	4%	3
ITWS	43	8%	5
ADS-B/CDTI Parallel Approaches	5	33%	19
WAAS or LAAS Parallel Approaches	5	52%	15
WSP	1	7%	6